ILC R&D at Fermilab Overview

(Main Linac and Superconducting RF)

Shekhar Mishra

Fermilab

Charge

- Review the goals of the ILC component of SMTF.
  - As presented do the elements form the basis of a program which will allow the U.S. to establish the technical capabilities in SCRF required to support a bid to host the ILC?
- Consider the following areas and offer comment as appropriate:
  - The “deliverables” that the ILC GDE can expect to receive from this program and their projected influence on the ILC design and/or preparations for construction.
  - The strategic approach outlined for cryomodule production and testing in view of the existing capabilities within the national laboratories and universities, and the adequacy of the proposed supporting infrastructure and resources.
  - The relationship between the SMTF plan and a more comprehensive U.S. industrialization plan in support of ILC construction.
  - The role of the photo-injector and its upgrades within the ILC program.

ILC-TRC Ranking

- The ILC-TRC Second report outlined the R&D needed for the ILC for its importance and urgency.
  - Ranking 1: R&D needed for feasibility demonstration of the machine.
  - Ranking 2: R&D needed to finalize design choices and ensure reliability of the machine.
  - Ranking 3: R&D needed before production of systems and components.
  - Ranking 4: R&D desirable for technical or cost optimization
- US Linear Collider Technology Option Study expand this study by the reliability and risk analysis.
- These studies guide SMTF R&D programs.

Ranking 1: Energy

- The feasibility demonstration for the ILC requires that a cryomodule be assembled and tested at the design gradient of 35 MV/m.
- This test should prove that quench rates and breakdowns, including couplers, are commensurate with the operational expectations.
- It should also show that dark currents at the design gradient are manageable, which means several cavities should be assembled together in a cryomodule.

To date no Cryomodule in the world exists that can satisfy these.

We need several (>100) to have confidence.

DESY TTF-II has multiple priorities and may not be able to carry out the long-term tests necessary at 35 MV/m

DESY X-FEL will focus on ~28 MV/m.

Ranking 2: Energy

- To finalize the design choices and evaluate the reliability issues it is important to fully test the basic building block of the linac.
  - This means several cryomodules installed in their future machine environment, with all auxiliaries running, like pumps, controls etc.
  - This test should as much as possible simulate the realistic machine operating conditions, with the proposed klystron, power distribution system and with beam.
  - The cavities must be equipped with their final HOM couplers.
  - The cavity relative alignment must be shown to be within requirements.
  - The cryomodules must be run at or above their nominal field for long enough periods to realistically evaluate their quench and breakdown rates.

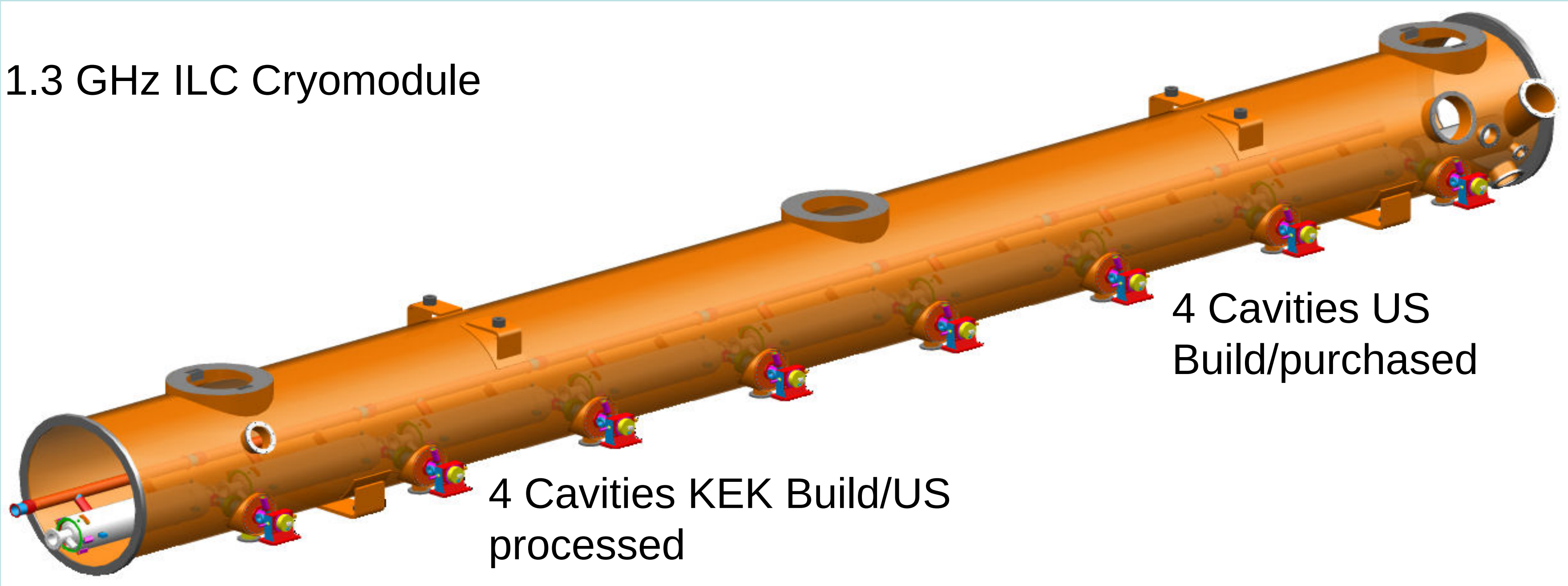
- ILC R&D needs to focus on these.
- DESY has been leading this effort but the focus of TTF is now on operation with limited beam time for 35 MV/m operations.
- X-FEL may not be able the answer to all the ILC questions.

Technology Studies: ILC-WG5 (ILC Workshop at KEK)

- Determine the maximum operating gradient of each cavity & its limitations.
- Evaluate gradient spread and its operational implications.
- Measure dark currents, cryogenic load, dark current propagation, and radiation levels.
- Measure alignment of the quadrupole, cavities and BPM in-situ using conventional techniques (e.g. wire or optical).
- Measure vibration spectra of the cryomodule components, especially the quadrupole magnet.
- Measure system trip rates and recovery times to assess availability.
- Develop LLRF system, exception handling software to automate system and reduce downtime.
- Evaluate failures with long recovery times: vacuum, tuners, piezo controllers, and couplers.

Superconducting RF Module & Test Facility (SMTF)

Main Goal: Develop U.S. Capabilities in high gradient (35 MV/m or Greater) and high Q (~1e10) superconducting accelerating cavities in support of the International Linear Collider.



SMTF Collaborating Institute and their representative

- Argonne National Laboratory: *Kwang-Je Kim*
- Brookhaven National Laboratory: *Ilan Ben-Zvi*
- Center of Advanced Technology, India: *Vinod Sahni* *(More institutions have been asked to join)*
- Cornell University: *Hasan Padamsee*
- DESY: *Deiter Trines*
- Fermi National Accelerator Laboratory: *Robert Kephart*
- INFN, Pisa : *Giorgio Belletini*
- INFN, Frascati: *Sergio Bertolucci*
- INFN, Milano: *Carlo Pagani*
- Illinois Institute of Technology: *Chris White*
- KEK: *Nobu Toge*
- Lawrence Berkeley National Laboratory: *John Byrd*
- Los Alamos National Laboratory: J. *Patrick Kelley*
- Massachusetts Institute of Technology: *Townsend Zwart*
- Michigan State University: *Terry Grimm*
- Northern Illinois University: *Court Bohn*
- Oak Ridge National Laboratory: *Stuart Henderson*
- Stanford Linear Accelerator Center: *Chris Adolphsen*
- Thomas Jefferson National Accelerator Facility: *Swapan Chattopadhaya*
- University of Pennsylvania: *Nigel Lockyer*
- University of Rochester: Adrian Melissions

Proposal was submitted to Fermilab on Feb. 18th 2005.

Interactions with DOE and GDE

Most of these institutions have joined with ILC R&D interest.

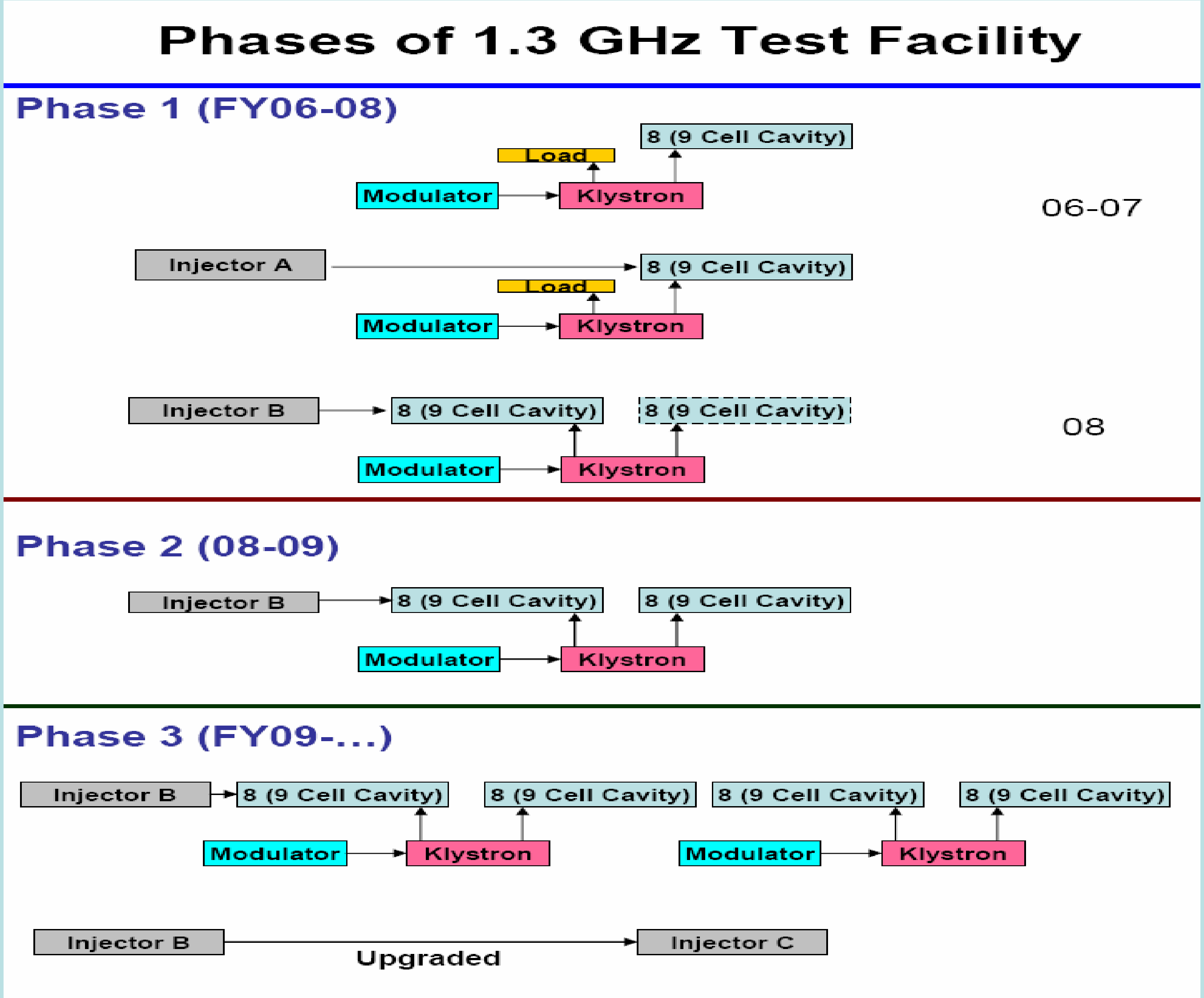
US-ILC Main Linac Responsibilities

- Fermilab has the responsibility of the Main Linac superconducting part in US.
  - We are coordinating this work with the collaborating laboratories.
- SLAC has the responsibility of the Main Linac RF power US.
  - We are developing modulator and purchasing klystron to get started based on existing design.
  - SLAC is doing R&D and will be taking a lead in this for ILC.

ILC R&D Goals

- Develop the capability to reliably fabricate high gradient and high-Q SCRF cavities in U.S. ($\geq$ 35 MV/m and ~1e10)
- Establish a prototype factory with infrastructure for the assembly of cryomodules at Fermilab.
- Fabricate 1.3 GHz high gradient cryomodules. Test cryomodules (2 deg K) and RF power components. Iterate design as fabrication and operational experience is acquired and designs are optimized.
- Establish a high gradient, 1.3 GHz cryomodule test area at Fermilab with a high quality pulsed electron beam using an upgraded A0 photo-injector.
- Demonstrate 1.3 GHz cavity operation at 35 MV/m with beam currents up to 10 mA at a ½ % duty factor. Higher currents or duty factors may be explored if the need arises.
- Investigate cost reduction strategies.

Proposed ILC Cryomodule Fabrication Schedule



Year	Cryomodule Number
06	1
07	2
08	3
09	4-5
10	5-6

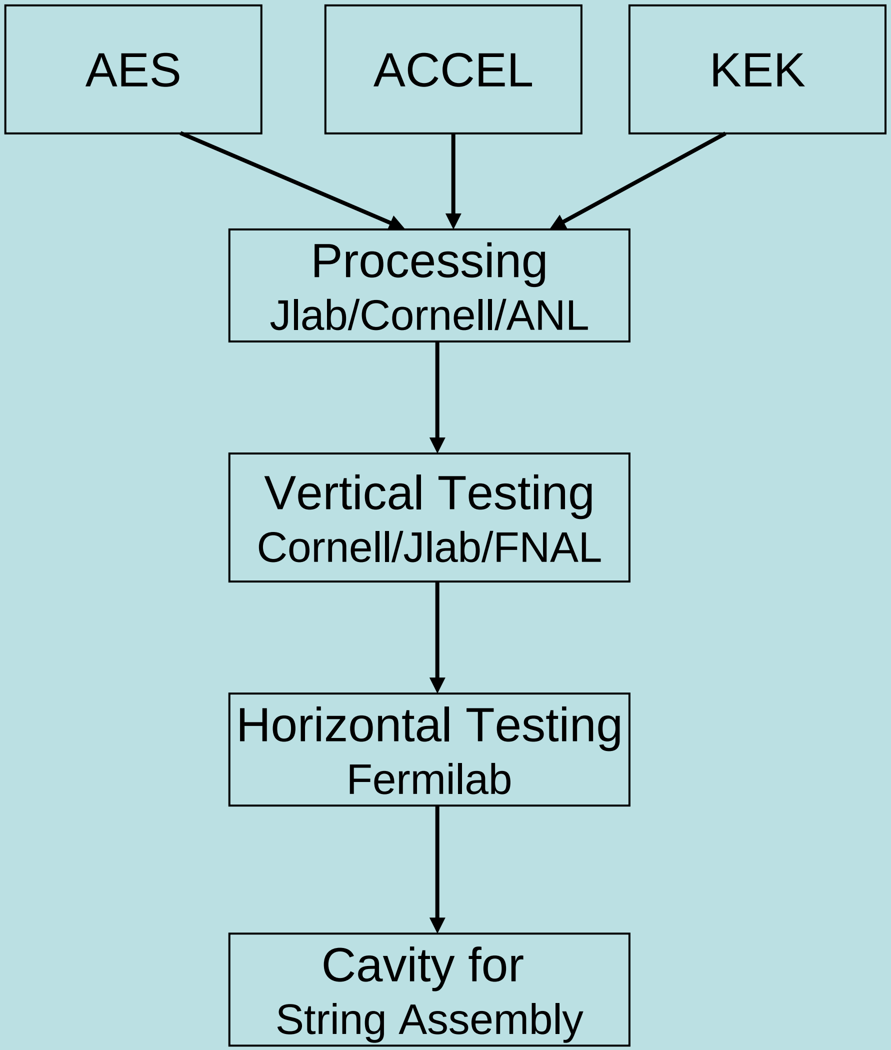
We are expecting that 4/6 will reach design gradient.

1.3 GHz Cavity Fabrication

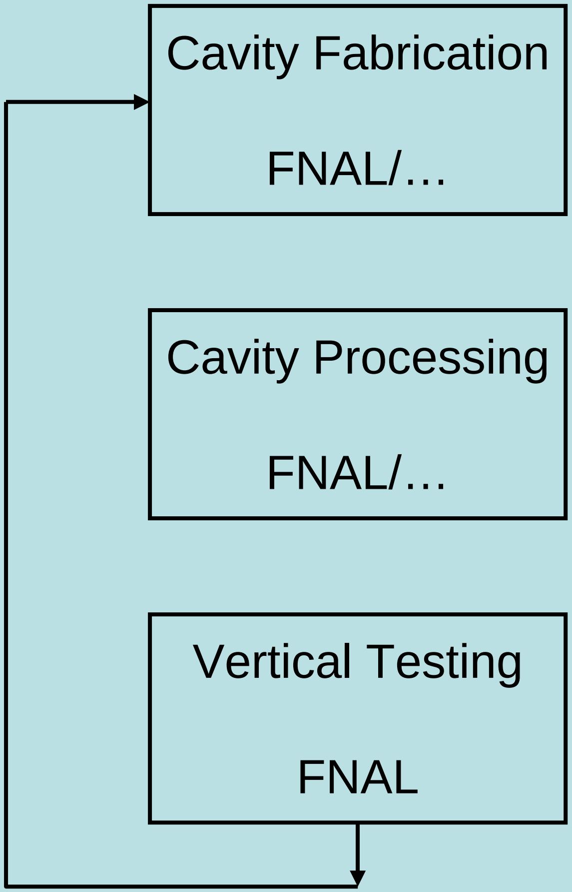
- We are converting all the DESY drawings in US system for US vendors.
- At present we plan to develop cavity in collaboration with Jlab, Cornell, ANL, SLAC and industries.
- In view of the ILC, we are developing plans for cavity fabrication. This would be driven by the need to master the cavity fabrication technology to achieve $\geq$ 35 MV/m. (Cavity fabrication $\leftarrow\rightarrow$ Vertical testing)

<u>Deliverable:</u> Cavity fabrication technology to reliably and cost effectively produce cavities with gradient $\geq$ 35 MV/m.

Cavity Fabrication



Perfecting the gradient technology



ILC Cryomodule

- We are developing infrastructure for cavity and cryomodule fabrication.
- The plan is to build the first US cryomodule which is a exact copy of TTF cryomodule (version 3+) (Ready by 06)
- Fermilab in collaboration with SLAC and DESY is making detailed Main Linac Low Emittance preservation simulation that will yield a new cavity alignment specification.
- There has been considerable discussion within ILC regarding the need to a 4th generation cryomodule.
  - Quadrupole package at the center
  - Quadrupole package as a separate unit
- We are proposing to hold a ILC workshop on 4th generation cryomodule need and design.

<u>Deliverable:</u> ILC Cryomodule design.

ILC Main Linac Simulation

Nominal Installation Conditions

Tolerance	Vertical (y) plane
BPM Offset w.r.t. Cryostat	300 μm
Quad offset w.r.t. Cryostat	300 μm
Quad Rotation w.r.t. Cryostat	300 μrad
Structure Offset w.r.t. Cryostat	300 μm
Cryostat Offset w.r.t. Survey Line	200 μm
Structure Pitch w.r.t. Cryostat	300 μrad
Cryostat Pitch w.r.t. Survey Line	20 μrad
BPM Resolution	1.0 μm

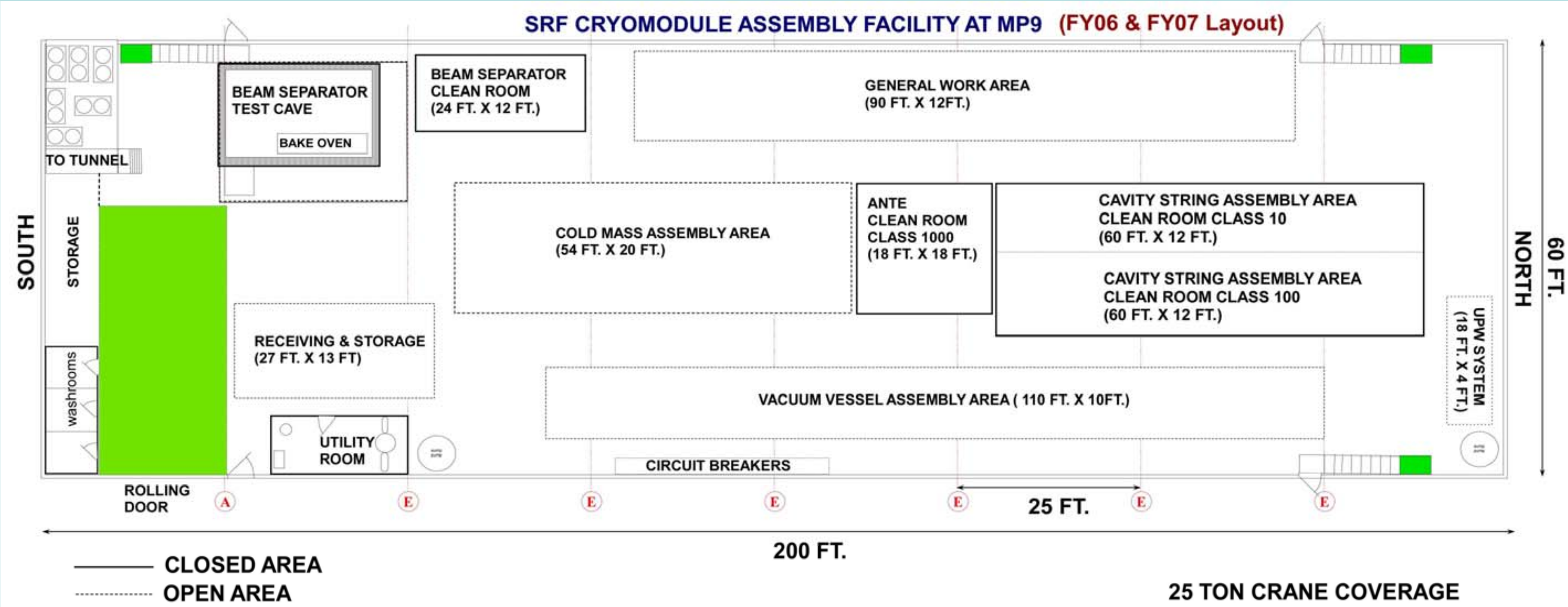
Not mentioned in TESLA TDR

10 μm in TDR, expect improved results using NLC X-band Cavity BPM R&D

- BPM transverse position is fixed, and the BPM offset is w.r.t. Cryostat
- Only Single bunch used
- No Jitter in position, angle etc.; No Ground Motion and Feedback
- No Quad Movers, Steering is performed using Dipole Correctors.

Cavity and Cryomodule

- Cavity is produced, processed and vertical tested outside Fermilab.
- Cavity is horizontally tested at Fermilab and assembled in string at MP9.
- Cryomodule fabrication test place at MP9. (Reqs signed)



RF Controls

- SMTF facility will help develop the LLRF system with ILC specification.
- We collaborating with DESY and participating in study at TTF.

Deliverable: LLRF System for ILC

ILC Instrumentation

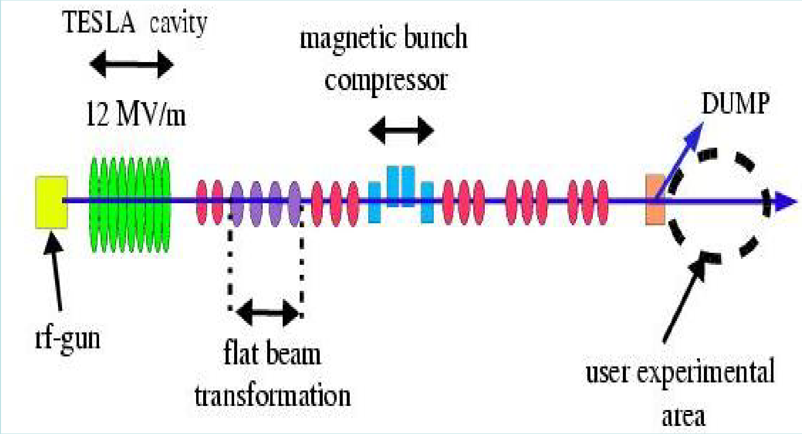
- A next generation ILC instrumentation is needed to meet the low emittance preservation specification. (BPM resolution 1 μm vs 10 μm)

- Since we will not be a beam operation facility it would provides an opportunity to investigate different instrumentation ideas in a realistic environment.

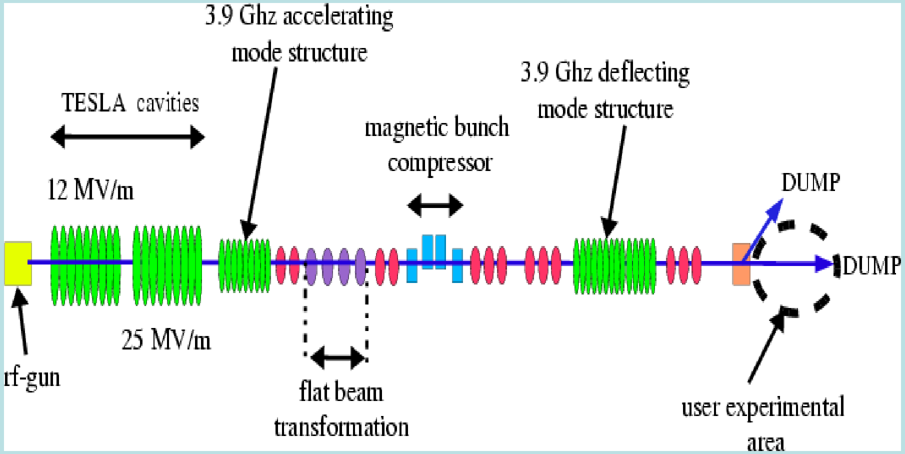
- We can also develop techniques on how to use the HOM position information in correlation with the BPM is aligning the beam to the cavities.

Deliverable: Instrumentation Development

The Fermilab NICADD Photoinjector Laboratory (FNPL)



FNPL Upgrade



•2nd incarnation of the TTF Injector II, with extended diagnostics,
• One normal conducting rf gun, one superconducting booster cavity
• Beam energy up to 16 MeV, bunch charge up to 12 nC
• Normalized emittance 3-4 π mm mrad (with 1 nC)
• Beam physics studies with high brightness beams
• Experimental area for advanced accelerator concepts
• Education of students

US Industrial Interaction

- US Industrial base need to develop in both technology and infrastructure for ILC.
- We have started initial industrial contact for the cavity fabrication works.
  - AES
  - ACCEL
- We are working with local industry in fabricating parts for the cryomodule. (At present plan is to assemble at Fermilab)
- Parson has made a visit to Fermilab to learn about ILC. Under discussion is cavity and cryomodule fabrication.
- Development of the US Industrial forum for ILC is being discussed. We are planning to hold a workshop for industry.

Technology Transfer: Industry

- In a MOU between Fermilab-Cornell we are purchasing 1.3 GHz cavities from AES.
- The cavities will be fabricated by AES and chemically treated and vertically tested *by AES* using the Cornell facility.
- So far there is no industry in the world that has learned how to chemically prepare and vertically test the 9-cell cavity.

Deliverable: Cavity & Cryomodule Technology transfer to Industry.

3.9 GHz Cavity Development

- 3rd Harmonic will operate in deceleration mode and linearize the beam bunch energy with time.
- The deflecting cavity will be used as a diagnostic to measure beam properties within the different time slices of the beam bunch.
- Deflecting cavity development will also be important for ILC crab crossing cavities

ILC Deliverables

- Cavity technology to routinely achieve >= 35 MV/m and Q ~e10.
- ILC Cryomodule with final design (4^{th} generation)
- RF controls (ILC type LLRF system)
- Test bed for new R&D in instrumentation (i.e. BPM resolution requirement 1 μm)
- Initial interaction with industry and technology transfer to industry.
- 3.9 GHz accelerating for bunch compressor and 3.9 GHz deflecting cavities as crab cavity at IR.

Resources Overview

- Charts of the $ from budget on infrastructure…